

DEPARTMENT OF COMPUTER SCIENCE  
COLLEGE OF SCIENCES  
OLD DOMINION UNIVERSITY  
NORFOLK, VIRGINIA 23529

**INTEGRATION OF LVLASO SYSTEM WITH ATN**

By

Dr. Ravi Mukkamala, Principal Investigator

Final Report

For the period ended August 11, 1996

Prepared for

National Aeronautics and Space Administration

Langley Research Center

Hampton, VA 23681-0001

Under

Research Grant Number NAG-1-1747

Wayne H. Bryant, Technical Monitor

Submitted by the

Old Dominion University Research Foundation

P.O. Box 6369

Norfolk, VA 23508-0369

September 1996

DEPARTMENT OF COMPUTER SCIENCE  
COLLEGE OF SCIENCES  
OLD DOMINION UNIVERSITY  
NORFOLK, VIRGINIA 23529

**INTEGRATION OF LVLASO SYSTEM WITH ATN**

By

Dr. Ravi Mukkamala, Principal Investigator

Final Report  
For the period ended August 11, 1996

Prepared for  
National Aeronautics and Space Administration  
Langley Research Center  
Hampton, VA 23681-0001

Under  
**Research Grant Number NAG-1-1747**  
Wayne H. Bryant, Technical Monitor

**Submitted by the**  
**Old Dominion University Research Foundation**  
**P.O. Box 6369**  
**Norfolk, VA 23508-0369**



September 1996

# **Integration of LVLASO System with ATN**

## **Final Report (NAG-1-747)**

**Ravi Mukkamala**  
Department of Computer Science  
Old Dominion University  
Norfolk, Virginia 23529.

### **Abstract**

We report on the work done as part of the NASA LaRC grant NAG-1-747. We have studied the ATN (Aeronautical telecommunications Network) in term of its architecture, its current applications, and its suitability in meeting the needs of Low-Visibility Landing and Surface Operations (LVLASO) system being developed by NASA. This report summarizes our findings.

## **1 Introduction**

The main objective behind proposing ATN to civil aviation community by ICAO is towards achieving fully automated air traffic management. Since Air Traffic management (ATM) involves the ground control, the airline operations/management, the aircraft, and auxiliary services such as weather reporting, it is a distributed service. While the avionics airborne and ground networks are static, the air-to-ground interconnections are themselves mobile. As the aircraft moves in space, from one control domain to another, the internetworking topology with respect to the end-to-end connection with one end user in the aircraft and the other on the ground changes dynamically. In addition, the added complexity of heterogeneous ground station capabilities as the aircraft travels in international terrains makes the problem more challenging.

Our interest is in analyzing a specific application domain (e.g., LVLASO) and determine their demands and data link requirements and specify its requirements in terms of ATN services.

ATN specific design decisions that are likely to affect the applications are:

- (i) ATN supports only connectionless mode of operation as an internetwork protocol. This means that each NPDU that traverses across subnets is to be treated as individual entities.
- (ii) The individual subnets could support either connection-mode or connectionless service within a subnet. Since connection-oriented services use less bandwidth and more

reliable, the ground-to-air mobile subnetworks are connection-oriented and the rest support either service.

- (iii) The application can specify its requirements in terms of the following QoS parameters: transfer frequency, throughput, priority, delay, reliability, cost, and security. In fact, as the flight is in different phases of a flight these requirements might change even for the same application.
- (iv) With the availability of multiple modes of communication that can be uniformly handled by the ATN router, the application designers can probably expect better support than the existing systems.

In addition, the application designers need to keep in mind the delays involved in such distributed and distant sessions as more and more applications are added. Also, the applications should be aware of the limited air-to-ground bandwidths. One needs to consider whether it is possible to design applications where much of the processing is done either on the ground or on the aircraft with minimal data exchanged via air-to-ground medium. A significant difference in the way designers ought to think is the presence of powerful computing power available on board and the airborne ATN router.

## 2 ATN Design Objectives

The ATN design allows communication services for different user groups:

- (i) Air traffic services (ATS)
- (ii) Aeronautical operational control (AOC)
- (iii) Aeronautical administrative communications (AAC)
- (iv) Aeronautical passenger communications (APC)

The design provides for different air-ground subnetworks and different ground-ground subnetworks, resulting in a common data transfer. ATN is the internetworking infrastructure developed by ICAO for the purpose supporting these goals.

Improved air traffic management( ATM), however, remains the primary objective behind ATN development. It is also to be observed that real success in ATM automation can only be achieved when the aircraft-based computer systems are designed and implemented as peers to their ground-based computers, as opposed to their current role as terminals or slaves in a master-slave relationship. In addition, it should be able to handle data received from the multiple data channels (VHF, SATCOM, Mode S) in a unified manner. In summary, the key to ATN's success are well-connected ground-based and aircraft-based ATN routers.

ATN routers would solve the problems of aircraft mobility, redundant channels of communication, and heterogeneous modes of communication. The applications that are built on top of the routers will then be the entities that really offer the ATM services.

Performance expectations from ATN are:

- Reliability

- Mobile hosts
- Redundant data paths
- Heterogenous data links
- bandwidth requirements dictated by applications
- Quality of Service guarantees

The development of ATM will require additional studies to enable the new and improved functions to be introduced, with emphasis on those that are made possible by air-ground data communications.

### 3 ATN Communication Protocol Architecture

ATN has adopted the ISO protocol architecture. Accordingly, the network layer manages the data link layer in order to transfer data between transport layer entities based on global address and QOS information. The transport layer can operate in either connection-oriented or connectionless mode.

ATN only supports connectionless internet protocols. Hence, any transport protocol operating within the ATN environment must be capable of correct operation using the connectionless network layer access provided by the ATN internet. Reliable end-to-end data transfer is the role of the ISO OSI transport layer.

Why has ATN chosen to support only Connectionless service at the network layer? The main reason is that IP is also connectionless with best-effort approach to delivery. The transport layer, which resides in the external system, is responsible for a connection-oriented service offered to higher layers. While the DoD's TCP/IP offers a complex transport layer with simple network layer, CCITT's X.25 offers simple transport layer and complex network layer (connection-oriented). The technical reasons for not adopting the TCP/IP suite of protocols for the ATN include:

- limitations of network address space that are currently becoming a big problem within the TCP/IP Internet;
- lack of the mechanisms to support QoS and priority;
- the inability of supporting routing policy mechanisms appropriate to support the internetworking needs of commercial, government and other organizations while allowing distributed control and administration of the ATN.

Mobile subnetworks tend to utilize free-radiating media (VHF/UHF radio, D-band satellite, or D-band secondary surveillance radar) rather than contained media (e.g., wire or coaxial cable); thus they exhibit broadcast capabilities in the truest sense. However, the available bandwidth tends to be extremely restrictive, leading to the use of bandwidth-conservative protocols. The result is that mobile subnetworks are treated as though they were broadcast networks in terms of media-coverage, and may require connection-mode subnetwork access protocols for efficient use of media bandwidth.

For the ATN CLNP (Connectionless network protocol), the QoS requested by the network service user (e.g., transport process) is a relative measure containing four elements:

- throughput
- transit delay
- residual error probability; and
- expense.

A ranking of these four may be explicitly indicated by the network service user.

For bandwidth efficiency purposes, the connection-mode subnetwork protocol is recommended for use in the limited bandwidth air-ground subnetworks. In the case of avionic or ground subnetworks, either mode could be used.

Transport operations could be either connection-mode (COTS) or connectionless-mode (CLTS). COTS would be selected where the peer application processes require the exchange of longer messages, or where end-to-end flow-control, error control and delivery acknowledgements are required.

CLTS would be selected where the peer application processes require exchange of TP-DUs with no end-to-end flow control or delivery acknowledgement. This service is primarily intended to benefit those applications that require a one-time, one-way transfer of data.

## 4 Perspectives on ATN

### 4.1 An individual user's perspective of ATN

The ATN is a data communications internetwork that:

- (i) provides a common communications service for all ATSC (Air Traffic Services Communication) and AISC (Aeronautical industry services communication) applications that require either ground/ground or air/ground communication services.
- (ii) integrates and uses existing communications networks and infrastructure wherever possible.
- (iii) provides a communication service which meets the security and safety requirements of ATSC and AISC applications.
- (iv) accommodates the different grades of service (QoS) required by each ATSC and AISC application.

### 4.2 Organizational perspective of ATN

An organization with one or more internal subnetworks, may have one or more ATN Routers. The ATN routers connect the subnetworks to the rest of the ATN network.

All host computers and ATN routers belonging to an organization correspond to a Routing Domain. Thus, within the domain, the ATN routers may exchange routing information to keep themselves up-to-date of the best routes to take for a host computer within that domain.

In addition, there may be one or more designated ATN routers to route CLNP packets to external destinations (i.e., outside their routing domain). These are referred to as Boundary Intermediate Systems (BIS).

Rather than exchanging connectivity information, as is done between routers within a Routing Domain, BISs advertise routes to each other, where a route consists of the set of addresses which identifies the destinations reachable over the router, and information about the route's path including the QoS and Security available over the route.

Mobile platforms such as an aircraft forms a routing domain by itself. This is due to the changes in connectivity as it moves in the area. For example, a long haul aircraft may move between coverage areas of different satellites; an aircraft flying over a land mass will fly between different M-Mode S subnetworks as it passes over different countries. And, at the same time, the applications on board the aircraft need to maintain contact with applications on the ground. Mobile platforms thus require special routing considerations. Thus each of these platforms contain an ATM router that is also a BIS.

To accommodate the special needs of the mobile Routing Domains, and the consequent rapid change of their connectivity, each aircraft is assigned to a fixed "home" domain. A route to an aircraft's home is known throughout the fixed ATN. The current route to an aircraft is propagated to the aircraft's home and those RDs along the path to the home only.

The ATN Transport service provider may operate in either the connection or the connectionless mode, depending on the user's requirements. In the connectionless mode, the Network Service Provider is relied on for resource management, while in the connection mode the transport provider must perform its own local EXPLICIT resource management and, additionally, map the QoS requests made in a connection mode sense into the connectionless style QoS requests expected by the Network Service. The ATN internetworking protocol is connectionless and operates an IMPLICIT resource allocations strategy. Many of the ATN subnetworks provide a connection mode service, and EXPLICIT resource allocation will be performed on these subnetworks.

## 5 QoS Framework of ATN

An application, in combination with the supporting upper layer protocols, is an ATN user. Each application will have defined requirements in terms of characteristics such as transit delay, throughput, error detection, security, or cost. Some applications, for example, may have strict transit delay and security requirements with little consideration for cost, while others may have very low needs for throughput and transit delay but high sensitivity to the expense.

Quality of Service or QoS refers to the level of communication service that an ATN user may expect to receive, defined in terms of the achieved service characteristics. QoS can be expressed in terms of requested, indicated, or expected QoS.

Requested QoS reflects the service characteristics desired by the service user. Indicated QoS is determined by the QoS parameters passed in protocol control information, and may reflect varying accuracy with respect to actual characteristics. Expected QoS is based on a combination of a priori knowledge and analysis of performance information received from the operation of routing protocols.

QoS requirements are indicated at the service boundary of each OSI layer, when ap-

propriate service elements are invoked, and each service provider attempts a best effort to satisfy the requested QoS.

With the exception of security, the layers above the transport layer simply pass their QoS requirements down directly to the service below. The transport service may pass requested QoS down to the network service, which then attempts to find a route which matches the QoS requirement, or alternatively, the transport provider attempts to optimize the use of available communications resources to provide the requested quality of service at minimum cost.

There is an important difference in the application of QoS between the different modes of OSI communications services. In the connection mode, the required QoS is requested by the user at the start of a connection, and the necessary communications resources are assigned, if available, in order to provide the requested QoS during the lifetime of the connection.

However, in the connectionless mode, QoS requirements have to be expressed separately each time the service is invoked. This does not permit explicit allocation of resources to meet QoS requirements, and instead implicit allocation has to be performed using extrapolations from past behavior.

Furthermore, QoS requirements may be expressed differently in the two modes. For example, throughput is a meaningful requirement for a connection mode, but has no meaning for a unidata (or connectionless service such as a datagram) service. Alternatively, cost is a simple one-dimensional concept in the connectionless mode, referring simply to the cost of sending the datagram. However, in the connection mode, cost may be multi-dimensional, with separate elements for data transfer and for maintenance of an open virtual circuit. For example, if a connection is kept open for 1 hour while intermittently sending 10 MBps of data, what is the cost of such service. There may be a fixed setup and tear-down cost, cost per Mbps of data sent, and cost per minute of maintaining the connection. The QoS metrics supported by ATN include:

- Transfer frequency—can vary depending upon traffic density, level of automation, flight phase, and local operational requirements.
- Throughput:
- Priority: Static and dynamic priorities
- Transfer delay:
- Reliability
- Cost—financial cost of communication—the application may specify a maximum acceptable cost.
- Security: Application specifies the level of protection required. A request for protection may also affect the route that the data takes through the ATN.

Once the QoS and the address of the destination are specified, other details such as the routing are transparent to the end-user.

In designing the applications, one of the important points to remember is:



“Different ground facilities may be equipped with different hardware/software capabilities. In fact, this may be completely unknown. How does one handle this? How are they handled now? I.e. as the aircraft flies through different territories, how is the pilot able to communicate with the ground?”

## 6 ATN Security model

ATN provides the following services at different OSI layers.

- (i) Peer Entity Authentication: Provides assurance that an "entity" (e.g. a protocol layer) is in communication with the peer entity that it claims to be in communication with it. Authentication of a peer entity may be provided at connection establishment only, or at all times during a connection.
- (ii) Data origin authentication: Provides a proof of the origin of unidata (i.e. connectionless data transfer).
- (iii) Access control: provides protection against unauthorized use of resources available via OSI (e.g., a subnetwork).
- (iv) Connection confidentiality: Provides for the confidentiality of all data exchanged over an applicable connection.
- (v) Connectionless confidentiality: provides for the confidentiality of unidata.
- (vi) Traffic flow analysis: uses statistical techniques to gain information from the analysis of traffic flows, and this security service provides protection from this form of monitoring and analysis.
- (vii) Connection integrity with recovery: assures the integrity of all data transferred over the applicable connection, and detects any modification, insertion, or replay of such data, and attempts recovery from the loss of integrity.
- (viii) Connection Integrity without recovery: similar to above service, but should any modification, insertion, or replay be detected, this fact is simply reported, and no recovery is attempted.
- (ix) Connectionless Integrity: provides assurance that a unidata item has not been modified.

## 7 ATN and LVLASO

LVLASO deals with low visibility landing and surface operations such as taxiing. Currently, LVLASO uses GPS aided by the corrections from the ground to determine the exact position of itself. In addition, the VHF broadcasted information from the ground is used to determine the position of other objects in the vicinity. The correction is also applied on these positional information to obtain more accurate (DGPS) positional knowledge. Each aircraft uses Mode-S to send its positional information. It receives the ground information through VHF. The ground-air link is 31.5 kbps.

From the current LVLASO experiments, it has been observed that (i) DGPS is much more accurate than GPS; (ii) The data link could be a bottleneck; (iii) even with the use of old correction information, DGPS worked effectively compared to GPS.

Currently, ground stations use ACARS format to send control and data information to the aircrafts. The GPS correctional information and the positional information received via Mode-S about the objects in vicinity are included here.

Currently, the squitter signals that are randomly emitted by aircraft SSR (secondary surveillance radar) Mode S transponders for collision avoidance system applications. For precision monitoring and surface surveillance, differential corrections passed via the Mode S data link have been used to achieve 3-to-5 meter positional accuracies out to 50 nautical miles.

The satellite-based air navigation system concept endorsed by ICAO foresees the enhanced use of communications, navigation and surveillance (CNS) to transition from air traffic control to air traffic management. In this system, the current system of voice communications is expected to be replaced by data messages. ATN will permit anyone in the air transport system to communicate with anyone else in the system. In general, ATN is an architecture of defined communications protocols and routing procedures that allow both air and ground end systems to communicate through a wide variety of media.

The aircraft is equipped with ACARS management unit. The message (generated either by the A/C crew or by other avionics sensors) is formatted by the ACARS unit and sent down using a data link. ACARS data is transmitted to a satellite which in turn delivered it to a satellite ground station and further forwarded to ARINC data network for further delivery to the destination on ground.

ATN is a communication architecture to pass data link messages between networks and terminals over various media. This architecture allows the end system on the aircraft to maintain a connection to the ATC system on the ground via the various air-ground and ground-ground subnetworks.

While the aircraft produces bit-oriented data in the RTCA 169 standards using ARINC 622 encoding process that converts bit-oriented message to character-oriented message. This is a temporary solution during transition to a complete ATN bit-oriented system.

One of the objectives of ATN is to convert the Air Traffic Control (ATC) concept into Air traffic Management (ATM). In this concept, the current system of voice communications is expected to be replaced by data messages.

Using ATN, the end system on the A/C will be able to maintain a connection to the ATC end system on the ground via the various air-ground and ground-ground subnetworks. This end-to-end connectivity provides positive confirmation that the communication is received at its intended destination. Some major features of ATN that could be used in LVLASO are:

- Reduces communication cost
- Use of commercial off-the-shelf equipment for ISO-compatible communications and information processing.
- Applications that are independent of the media used to transmit data.
- Allows for policy-based routing to optimize performance or cost.

- Facilitates contract management—End-systems communicate to set up connections, indicate frequency of reporting, and communication parameters.
- Provides end-system to end-system connectivity. Allows direct controller-pilot communication capability through whatever intermediate networks are necessary to provide the connection.
- Ensures high reliability through the use of transport layer protocol (TP4).
- Supports data compression capabilities. Large messages can be compressed and transmitted as text files or graphics.

The bit-oriented formats of ATN (as opposed to character-oriented formats of ACARS) offer several benefits including:

- Data compression—existing data links gain added capacity for message traffic.
- Graphics can be transmitted efficiently for weather, navigation, etc.
- Off-the-shelf software is readily available to support bit-oriented protocols.

## 8 Conclusion

From our study of ATN and LVLASO systems, we conclude that the communication structure design of LVLASO could be simplified by the use of ATN. However, LVLASO can only use the ground-to-ground and ground-to-air communication components of ATN. In addition, it is not clear if ATN can in fact provide the tight QoS requirements of LVLASO during aircraft landings and take-offs. Much of these answers will be available as and when the ATN systems get implemented. But since ATNs are going to be a reality in the near future, LVLASO designers should take this factor into consideration and study the implications.

## References

- [1.] Bauhof, C. R., "ATM and FIS data link services," *IEEE Aerospace and Electronics System Magazine*, Vol. 9, No. 3, pp. 38-42, March 1994. (Also in *12th AIAA/IEEE Digital Avionics Systems Conference*,
- [2.] Cobley, G.A., "Integrated SATCOM/ACARS," —it 3rd Annual Intl. Telecommunications Symp. on Data Link Integration, pp. 13-19, May 1991.
- [3.] Colliver, F., "Aeronautical Telecommunication Network Panel: Draft ATN Standards and Recommended Practices," October 1994.
- [4.] Ferris, K.D. and G.R. Gatens, "An internetworking Brouter for avionics applications," *Conf. SPIE - The International Society for Optical Engineering*, Vol. 1799, pp. 231-233, 1993
- [5.] Gallegos, S.K., W.B. Link, and D. Thomson, "Innovation approaches for implementing the aeronautical telecommunications network," *12th AIAA/IEEE Digital Avionics Systems Conference*, pp. 98-103, Oct. 1993.

- [6.] Knoernchild, G.F., "Digital communications technology for air transport applications," *11th AIAA/IEEE Digital Avionics Systems Conference*, pp. 47-50, Oct. 1992.
- [7.] Nilsson, J and H. Lans, "The GNSS transponder: A cost-effective worldwide GNSS-based civil aviation CNS/ATM, ATC, ATN data link and collision avoidance concept," *Journal of Navigation*, Vol. 47, No. 3, p. 403-426, Sept. 1994 pp. 92-107, Oct. 1993.)
- [8.] Olson, R.R., "The airborne open system interconnection data link test facility," *11th AIAA/IEEE Digital Avionics Systems Conference*, pp. 509-513, Oct. 1992.
- [9.] I.L. Ray, "Aeronautical OSI profile development and the integrated avionics architecture," —it 3rd Annual Intl. Telecommunications Symp. on Data Link Integration, pp. 179-181, May 1991.
- [10.] Shivley, C.A., "Capacity as a consideration for providing aeronautical mobile satellite air traffic services in the US domestic airspace," *IEEE PLANS'92 Position Location and Navigation Symposium*, pp. 231-239, 1992. (Also in *IEEE Aerospace and Electronics System Magazine*, Vol. 7, No. 6, pp. 51-58, June 1992.)

# ATN: Aeronautical Telecommunications Network

Ravi Mukkamala

Department of Computer Science  
Old Dominion University  
Norfolk, Virginia 23529

## Organization

- Motivation
- Architecture
- User Groups for ATN
- Users' perspective of ATN—individual, organizational, and mobile users.
- Routing
- QoS Framework
- Public/Private Investment Model for ATN
- Applications Development
- Operational Requirements
- Flight information services over ATN

## Motivation

“To fully utilize automated air traffic management systems (ATM), we need a global networking infrastructure—internetworking of computer systems in fixed ground-based and mobile aircraft-based locations.”

Increased use of distributed ATM automation requires

- data communication between aircraft-based and ground-based computers.
- a more richly connected and more flexibly configured data network infrastructure.
- aircraft-based computer systems that are designed and implemented as data processing and networking peers to their respective ground-based computers.

## User Groups for ATN

- **Air traffic services (ATS)**—ensures safe and efficient movement of aircraft during all phases of operations; include, ATC, airflow management, and air space management.
- **Aeronautical operational control (AOC)**—safety service, part of the responsibility of an aircraft operator (airline) and deals with the initiation, continuation, diversion or termination of a flight in the interest of the safety of aircraft, and the regularity and efficiency of a flight.
- **Aeronautical administrative communications (AAC)**
- **Aeronautical passenger communications (APC)**

Basically it will provide services to pilots, the Airlines, FAA, Traffic controllers, passengers, and other service providers.



## **Users' Perspective of ATN**

The ATN is a data communications internetwork that

1. provides a common communications service for all ATSC (air traffic services communications) and AISC (Aeronautical industry services communications) applications that require either ground/ground or air/ground data communications services.
2. integrates and uses existing communications networks and infrastructure wherever possible.
3. provides a communications service which meets the security and safety requirements of ATSC and AISC applications.
4. accommodates the different grades of service required by each ATSC and AISC application.

The ATN (or OSI) architecture deliberately places the responsibility for routing and maintaining an internetwork's operational status on the "routers" and therefore enables the End Systems to have only a minimal networking capability.

## **The Individual ATN User**

ATN provides its users with a robust and reliable communications service, together with the option of a datagram service.

- A user's access to the ATN is first via an "access network" such as an Ethernet or an X.25 PSDN, and then an ATN Router. In addition to supporting the use of access sub-network, it should also support the Connectionless Network Protocol.
- Data transferred using CLNP is formatted as a block of data preceded by a protocol header containing the addresses of the sender and destination, the priority of the data, any security label associated with it, and QoS requirements. Header and data must not together exceed 64 kilobytes.
- Obviously, simple CLNP does not guarantee a user that the packet is delivered to the ATN router. In cases where such a guarantee is needed, a transport protocol should be used. Thus the individual user is not exposed to the complexities of the ATN Router.

## The User as an Organization

An organization that provides ATN service to several individual users operates one or more ATN Routers and one or more subnetworks of its own. In fact, the portion of the ATN operated by the organizational user may be no more than a single ATN Router.

- All host computers and ATN Routers operated by an organization is defined as a single Routing Domain. Within an ATN Routing Domain, there will be one or more ATN Routers that are permitted to route CLNP packets to **external destinations**, i.e., addressed destinations that are located in the “rest of the ATN.” These routers are known as Boundary Intermediate Systems (BISs) because they exist at the boundaries of Routing Domains.
- For inter-domain communications, ATN requires that BISs communicate directly over a common subnetwork. BISs advertise routes to each other, where a route consists of the set of addresses which identifies the destinations reachable over the router, and information about the route’s path including quality of service and security available over the route.
- It is the BIS’s responsibility to determine which routes, if any, it will advertise to another BIS, and the use it will make of routes which it receives. a policy-based routing enables users to control external access to their communications resources, and to protect themselves from problems elsewhere in the internetwork.
- Finally, it is intended that ATN interconnections are coordinated on both a regional and worldwide basis, so that ATN backbones (of Routing Domains offering transit facilities) are

created, with either a clear apportionments of costs, or a known tariff, for use of transit facilities. This way users can gain access to the full capabilities of the ATN quickly and cheaply.

## Mobile Users

An aircraft may attach to different mobile subnetworks during course of its flight. A long haul aircraft may move between the coverage areas of different satellites; an aircraft flying over a land mass will fly between different Mode S subnetworks as it passes over different countries.

- In the ATN, mobile platforms are treated in a similar manner as organizational users. That is, the systems on board an aircraft are required to form a Routing Domain and hence must include an ATN Router that is also a BIS.
- In order to handle the rapidly changing topology (and hence the routing information) due to the mobile BISs, the concept of “home” of an aircraft is introduced.
- The ATN routing policies ensure that the routing information of an aircraft is propagated to the aircraft’s home and those RDs along the path to the home only. The destination address within an aircraft has a prefix which is an address of its home. Accordingly, packets directed to the aircraft first reach either the home or any RD that is on the current path and directed from there on.

## QoS Framework

- QoS or Quality of service refers to the level of communication service that an ATN user may expect to receive.
- Transit delay, throughput, error detection, security, and cost are some example QoS requirements.
- QoS can be expressed in terms of requested, indicated, or expected QoS parameters.
  - Requested QoS—service desired by the user.
  - Indicated QoS—QoS parameters passed in protocol control information, and may reflect varying accuracy with respect to actual characteristics.
  - Expected QoS—based on a combination of a priori knowledge and analysis of performance information received from the operation of a routing protocol.
- QoS requirements are indicated at the service boundary of each OSI layer, and each service provider attempts a best effort to satisfy the requested QoS.
- Connectionless vs. connection-oriented mode: In the connectionless mode, the QoS requirements have to be expressed separately each time the service is invoked. However, in connection mode, it is only requested at the start of a connection. In addition, QoS requirements may be expressed differently in different modes. For example, throughput has no meaning in a unitdata service. Similarly, cost is a multi-dimensional concept for a connection service.

## QoS Offered by ATN

To enable the communication network to determine and provide the required service, the end-user data has to be accompanied by quality of service (QoS) parameters and addressing information. QoS parameters:

- **Transfer frequency:** Total number of transferred end-user messages and files per unit of time per end user. It depends on air traffic density, level of operation, flight phase, and local operational requirements.
- **Throughput:** Depends on the transfer frequency and the size of the messages/files.
- **Priority:** A predetermined static priority based on the type of the message (e.g., distress calls have priority 1, and meteorological messages have priority 5); and dynamic priority which depends on the situation (e.g., normal or alert).
- **Transfer delay:** Total time necessary to transfer message/file from sender to receiver. An end-user can specify maximum transfer delay for a connection. Processing delay at the gateways and other processors, and link delay in the subnetworks dictate this delay.
- **Reliability:** Probability that an end-user message/file is correctly received by the receiving end-user.
- **Cost:** The application may specify a maximum acceptable cost.
- **Security:** When needed, ATN users can specify required security services. This may affect the route chosen by the system. In addition, there may be limits placed on the communication subnets. Mode S subnetwork is restricted to data

relating to flight safety and regularity, while commercial service providers may restrict access to their networks to customers with prearranged credit facilities.



## Public/Private Investment Model for ATN

- Benefits:
  - Reduced costs providing communication services to users (e.g., airlines) through the use of shared avionics and networking resources;
  - Increased communications reliability and capacity through the ability to use any public or private transmission paths interoperably;
  - Increased ability to exchange complex information accurately and efficiently between ground and airborne platforms, resulting in flight time reductions and greater fuel efficiency.
  - The benefits to general aviation are more likely to accrue from increased safety and additional services, such as flight information services (e.g., weather information).
- Need to improve control over operating expenses through the effective use of communications and navigation is the motivation for ATN.

## **Applications Development**

The promised benefits of ATN will materialize mainly from the applications. Three candidate applications for initial implementation are:

- Two-way Data Link (TWDL): It offers a mapping of today's pilot-controller dialogue onto the data link. The application message elements include altitude assignments, crossing constraints, lateral deviations, route changes and clearances, speed assignments, and requests for information. Standards for this dialogue are currently underway or already completed.
- Context management application (CMA): To standardize aircraft-discovery and application capability exchange.
- Automatic dependent surveillance (ADS): Provides periodic emergency position reports including the capability for emergency mode reporting.

## Operational Requirements of ATN

Who is responsible for what and what kinds of information the operators will be expected to manage?

- ATN router transfers data from one subnetwork to another and is able to choose the best route in order to access each attached subnetwork.
- Functional model: (1) Fault management (2) Accounting management (3) Configuration management (4) Performance management, and (5) Security management.
- Organizational model: Describes the distributed nature of management and identifies an organization of management environment. (1) Manager (2) Agent
- Information model: Describes the model in terms of management objects.

## **Flight Information Services Application Over ATN**

FIS provides weather and aeronautical services.

- Hazardous weather advisory—issued by the National Aviation Weather Advisory Unit to warn en route aircraft of the development of potentially hazardous weather conditions.
- Surface observation report (SA)—issued hourly.
- Terminal Forecast (FT)—24-hour prognosis of the surface weather within the vicinity of an airport.
- Route-oriented service